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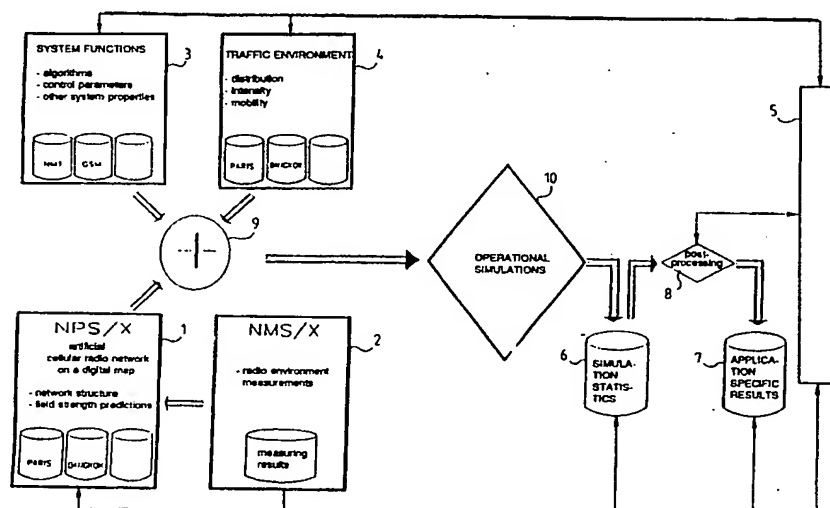(75) Inventor/Applicant (for US only) : OTS, Markus [FI/FI]; Tehtaankatu 12 E 66, SF-00140 Helsinki (FI).

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(54) Title: METHOD AND SYSTEM FOR PLANNING A CELLULAR RADIO NETWORK

(57) Abstract

The invention relates to a method and a system for planning a cellular radio network. The method comprises creation (1) of a model representing the cellular radio network and its radio environment on a digital map. In the invention, the method further comprises adding system properties (3) affecting the traffic control process of the cellular radio network to the model representing the cellular radio network and its radio environment for route specific operational simulation (10) of the cellular radio network. The simulation preferably utilizes subscriber mobility models and immobile and/or mobile individual subscribers (4) generated on the digital map. The simulation events are stored (6) separately for each street, location, network element and/or cause. The optimization (8) of the parameters of the cellular network is performed on the basis of the stored information. Simulation of an operating cellular network on the basis of statistical data obtained from the network allows an adaptive control of the system parameters.

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Method and system for planning a cellular radio net-
work

The invention relates to a method for planning
a cellular radio network, comprising creation of a
model representing the cellular radio network and its
radio environment on a digital map.

Cellular radio network planning can be divided
into coverage, frequency, capacity, parameter and
transmission planning. Planning applications based on
digital maps have recently been developed for cover-
age, frequency and capacity planning. Such planning
applications enable the modelling of the radio
environment of the cellular radio network as a func-
tion of location. One example of such planning
applications is the Network Planning System NSP/X of
Nokia. The operation of the software is based on a
mathematic propagation model for calculating the
coverages of base stations located on a digital map.

Another example of conventional network plan-
ning tools is disclosed in WO 90/10342 wherein radio
channels radio are allocated to the cells by utili-
zing an exclusion matrix presenting the interaction
between the cells in the system. The allocation of
radio channels is iteratively changed until it is
optimal from the point of view interference.

One subarea of radio network planning, i.e. the
definition of network parameters has conventionally
been carried out manually by applying the method of
"trial and error". Such network parameters include
hand-over parameters, subscriber station and base
station power control parameters and frequency
hopping parameters. Parameter planning starts by de-
fining a so-called "intelligent guess" for proper
parameter values, which are then applied as such to

the base stations of a planned and established cellular network. Information is then collected on the operation of the real radio network and analysed, and required changes in the network parameters are made

5 on the basis of the analysis, which usually means a new "intelligent guess". A problem with the operational analysis of radio networks is the acquisition of requisite feedback information. The most important sources of feedback information have usually been the

10 statistics of the mobile switching centre and the feedback from the network users. Within the most critical areas of the network, it is also possible to perform actual field strength measurements, on the basis of which one attempts to define proper para-

15 meter values. However, this process is extremely slow and laborious, and the network performance to be obtained by it is only satisfactory.

Careful parameter planning thus always requires a good knowledge of the local radio environment of

20 the real cellular network as well as reliable estimations of the effects of the different control parameters in the heterogeneous radio environment typical of cellular networks. Problems associated with the parameter planning have become more concrete

25 with the introduction of dense micro cell networks. In addition, the parameter planning will become even more important with the introduction of GSM mobile networks, which is due to the decreased cell size and the more diversified and more complicated control

30 algorithms and control parameters. Therefore the effect of control parameters on the performance of real cellular radio networks will be a matter of great importance.

The object of the invention is a method and a

35 system for planning a cellular radio network, which

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not only offers more efficient parameter planning
than previously but also enables full operational
analysis on the basis of which the performance of the
cellular network can be optimized.

5   This is achieved by means of a method according
to the invention, which is characterized in that the
method further comprises

adding of system properties affecting the traf-
fic control process of the cellular radio network in
10   connection with said model representing the cellular
radio network and its radio environment for route
specific operational simulation of the cellular radio
network,

optimization of the parameters of the cellular
15   radio network and full operational optimization of
the cellular network on the basis of statistical si-
mulation results describing the operation of the net-
work.

The invention is based on the idea that the
20   operational simulation of cellular radio networks is
transferred to a heterogeneous cellular and radio
environment modelled separately for each network on a
digital map. By adding the subscriber mobility models
and the system features of the radio network to be
25   simulated to the real cellular radio network created
on the digital map, a practical simulation concept is
achieved by means of which the operation of the real
cellular network can be analysed through simulations
in various conditions and with various parameter com-
30   binations. Network control functions occurred during
an operational simulation performed in the artificial
network and radio environment are stored and the
obtained statistical information about the operation
of the network can be subsequently utilized as feed
35   back data so as to localize the critical areas of the

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radio network to be simulated and to alter the network parameters at least in these areas. The effect of the altered parameters can be tested immediately by performing a new operational simulation and analysing the operation of the network on the basis of the obtained statistical information. This kind of iterative proceeding enables an optimal adjustment or tuning of the network structure and parameters even before the real network has been established. The method according to the invention can also be applied in existing networks for the analysis of the interdependence between the cell specific traffic control parameters and the heterogeneous (local) radio environment of the real cellular network. In place of the calculated field strength values, it is thereby also possible to utilize field strength values measured from the real network.

In the preferred embodiment of the invention, simulations are realized by individual subscribers, which enables very a many-sided collection of information and further applications. The simulation functions can be stored separately for e.g. each street, site, network element or cause. Active subscribers are generated by random processes based on the predicted or actual call statistics of the radio network to be simulated and/or on the subscriber penetration. The generated subscribers may be relatively immobile, such as handportables, or they may move within the area of several cells during the call, as is typical of vehicle stations. Mobile subscribers can be generated e.g. by random processes based on street specific traffic statistics, and they can be used for simulating load effects caused by subscriber traffic and call control procedures.

The invention also relates to a system for

planning a cellular radio network, comprising an
interactive means for creating a model representing
the cellular radio network and its radio environment
on a digital map comprising terrain and topology in-
5   formation, the model comprising at least base station
locations and antenna locations, antenna powers and
antenna directions thereof so defined that radio
coverage areas calculated on the basis of a pre-
determined radio signal propagation model and the
10   information provided by the digital map cover entire-
ly a desired geographical area. The system is charac-
terized in that it further comprises a means for
generating active subscribers to be positioned on the
digital map and radio links established by said
15   active subscribers for simulating said model;
a means for determining at least field strength and
interference conditions at each location point of
each generated active subscriber during the radio
link in said model of the radio environment created
20   on the digital map; a means for simulating system
functions associated with the base station selection,
base station change, channel allocation and active
connection control of the subscribers generated by
the generating means on the basis of the determined
25   field strength and interference conditions and in
accordance with the selected system control
algorithms and parameters of the cellular radio net-
work; a means for storing the event data of the func-
tions performed by the simulating means; and means
30   for changing the system control parameters on basis
of the simulation results.

One aspect of the invention is a control system
for a cellular radio network, comprising means for
obtaining statistical data of operation of an opera-
35   ting cellular network and means for altering control

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parameters of the cellular network on the basis of said obtained statistical data. According to the invention said means for altering said control parameters further comprise

5   means for storing a model of the cellular radio network and its radio environment on a digital map comprising terrain and topology information, the model comprising at least base station locations and antenna locations, antenna powers and antenna direc-

10   tions of the cellular network,

         a means for generating active subscribers on the digital map and radio connections established by said active subscribers according to said statistical data obtained from the operating cellular network,

15   a means for determining at least field strength and interference conditions at each location of each generated active subscriber during the radio link in said model of the radio environment created on the digital map;

20   a means for simulating system functions associated with the base station selection, base station handover, channel allocation and active connection control of the subscribers generated by the generating means on the basis of said determined field

25   strength and interference conditions and in accordance with the system control algorithms and parameters of the cellular radio network; and

         a means for storing the event data of the functions performed by the simulating means,

30   means for changing the system control parameters on basis of the simulation results.

         In the following the invention will be described in more detail by means of embodiments with reference to the attached drawings, in which

35   Figure 1 shows a flow chart illustrating the

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most important aspects of the planning method
according to the invention;

Figure 2 shows a flow chart illustrating a
traffic generation process according to the inven-
5   tion;

Figure 3 is a more detailed block diagram of
the system block of Figure 1;

Figure 4 is a diagram illustrating the presen-
tation of statistical simulation information to the
10   different system components of the cellular network;

Figures 5a to 5f are graphic outputs for the
presentation of statistics on the number of calls,
quality of calls, and number of hand-overs on a
graphic user interface, for instance;

15   Figures 6a to 6f show an example of the prin-
cipal features of a manual analysis of a cellular
network on the basis of the graphic representations
of operational statistics; and

Figure 7 is a block diagram of the connection
20   of the system according to the invention to an oper-
ating cellular network.

The main principle of the planning method and
system according to the invention appears most easily
from the combined block diagram and flow chart of
25   Figure 1. In Figure 1, functions of a certain type
are grouped into separate blocks so as to obtain a
modular structure which is not necessary but usually
very advantageous as it enables the utilization of
the same method and system in the operational simula-
30   tion and analysis of almost all cellular type systems
and networks. The principal features of each block
will be described below.

Block 1 is an interactive software package for
network design which forms the basis of the network
35   planning. It provides for the creation of the struc-

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ture of the network to be simulated and a model representing its actual heterogeneous radio environment on a digital map. The digital map is a prerequisite for computerized network planning and it usually provides information about the area under planning concerning at least the topography (height of terrain), type of terrain and roads/streets. By employing the software of block 1 the operator positions the base stations of the cellular network on the digital map and calculates the coverages of the base stations by means of a mathematical propagation model included in the software.

In the preferred embodiment of the invention, the functions of block 1 are realized by the Network Planning System NPS/X of Nokia Telecommunications Inc.

The planning system may also contain the practical measuring system shown in block 2, such as the Network Measuring System NMS/X of Nokia, for performing practical measurements in actual terrain and in the network, and the results so obtained (e.g. field strength values) can be used as feedback information in the network planning.

Subscriber traffic required for the simulation of the cellular radio network and its radio environment created in block 1 is created and controlled in block 4. The subscriber traffic may consist of deterministic moving of one subscriber or random type mass traffic. In the former case, simple route calculation is mainly employed, and no special mobility models are needed. Mass traffic provides for the modelling of the load effects caused by the subscriber mobility in the cellular network, which requires that the subscriber mobility and the local traffic intensity should be modelled.

The system specific properties of the cellular radio network to be planned in each particular case are found in block 3. Block 3 contains the system specific call control algorithms with their network

5   element specific parameters and other possible system properties affecting the radio environment. The purpose of block 3 is to monitor the state of the radio environment as a function of the moving of the subscribers generated on the digital map, and the per-

10   formance of functions simulating the required network control procedures. In this description, the primary emphasis will be given to properties specific to the GSM cellular radio system; however, by modifying the contents of block 3, the planning system of Figure 1

15   can be easily adopted to the planning and simulation of the NMT cellular radio system or some other system.

The simulation concept according to the invention is obtained when subscriber traffic is generated

20   by means of block 4 in the radio network and its heterogeneous artificial radio environment created on the digital map in block 1, and the system specific functions of block 3 are applied to the abovementioned operating network, as illustrated by

25   elements 9 and 10 in the flow chart of Figure 1. Network control events that occur during the simulations (block 10) are stored as simulation statistics in a data base 6. Simulation can also provide real-time graphic representations, but the actual utility

30   applications are usually realized by processing the simulation statistics stored in the data base 6 in block 8 by special further processing programmes so as to obtain desired application specific results.

The system further comprises a graphic inter-

35   active user interface 5 for performing the network

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planning of block 1 and subsequent changes (in power
levels, for instance); for performing the initial
definitions and changes (such as parameter
selections) in blocks 3 and 4; for starting the simu-
5   lation; possibly for monitoring graphically the simu-
lation in real-time; for initializing and starting
the further processing programmes; and for displaying
the obtained results on a graphic display. The
interactive graphic user interface 5 naturally
10   usually comprises a high-resolution colour graphics
display, a keyboard and a mouse.

In the preferred embodiment of the invention
the system runs on a Sun workstation and the user
interface is implemented on top of Sun View, which is
15   a system supporting interactive, graphics based
applications running within windows.

As mentioned above, block 1 contains digital
map information about the area to be planned, i.e. a
digital map. There are different types of information
20   that can be digitized and used for the coverage pre-
dictions. The most important information types from
the point of view of network planning are topography
(terrain heights), area types, roads and traffic
density. There also exist various ways of data pre-
25   sentation, but the raster format seems to be the most
suitable. The map area is thereby divided into raster
units (area pixels), which may be rectangular or
square-shaped, typically having a size of 50 m - 500
m in cellular radio applications. For the micro cell
30   modelling, which is required in dense urban environ-
ments, more information and higher resolution maps
should be used. Information about the buildings and
streets is essential, so that a pixel size of about
10 m is reasonable. The streets can be stored in
35   vector format.

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The operator positions the network elements, primarily base stations BS, at desired locations on the digital map, and determines their antenna location, antenna power, antenna direction and fre-
5   quency allocation. The object is to attempt to find optimal locations and parameters for the base stations so that the coverages of the base stations cover the desired area completely with appropriate overlapping. The purpose of frequency planning is to
10   determine a frequency re-use pattern to be applied and then base station specific frequency groups so as to minimize the level of network interference (and to meet the capacity requirements). Capacity planning defines the number of base station specific channels
15   so that local capacity requirements are met (this has a certain connection with the frequency re-use pattern).

The coverage of a cell is an area within which the field strength of the base station exceeds a pre-
20   determined threshold value. In the invention, the coverage predictions of the base stations positioned on the digital map are determined by a special radio signal propagation model, such as the Okumura-Hata model, utilizing the topography and area type inform-
25   ation of the numeric map and various system specific calculation parameters. In this way a field strength matrix is calculated for each area pixel of the digital map, containing a predicted value of the field strength of each base station positioned on the
30   map at the location. Values representing signal strengths are obtained directly from the above-mentioned matrices by converting the field strength values into dBm values.

Traffic generation performed by block 4 is
35   illustrated by the flow chart of Figure 2. In the

preferred embodiment of the invention, the simulation
is realized by individual subscribers. Typically, the
subscriber equipments of a cellular radio network can
be divided into vehicle stations and handportables.
On the basis of these equipment types, the radio net-
work subscribers can be further divided into two
groups which differ from each other mainly in
mobility. Handportables are usually relatively im-
mobile while vehicle stations may move within the
area of several cells during a single call.

Due to the constant mobility of the vehicle
stations the system has to perform active call
control procedures in order to maintain a call. To
simulate these procedures and at the same time the
load effects of the subscriber traffic, a traffic
model has been developed for the vehicle stations,
which realizes the generation of active calls and
controls the moving of the subscribers. Block 21 in
Figure 2 contains information about the local penet-
ration of the subscriber equipments and statistics on
the number of calls (such as number of calls per sub-
scriber equipment), on the basis of which the in-
tensity of the calls to be generated (block 23) is
determined by an appropriate random process (block
22). Block 24 contains call length statistics, on the
basis of which the duration of each call (block 26)
is determined by another random process 25. Block 29
contains e.g. statistics on street specific traffic
amounts (traffic density, speed distribution, etc.),
on the basis of which the location on the digital map
(block 27), direction of propagation (block 30) and
rate of propagation (block 30) are determined for
each call by random processes 28, 31, and 33. In this
way active subscribers moving independently in a pre-
determined direction at a predetermined rate in a

digitized street network 36 of the digital map 35 can be generated by combining (block 34) the information from the blocks 33, 26, 27, 30 and 32. When the active mobile subscriber arrives at a node (i.e.

5   crossroads), a new direction and propagation rate are selected (blocks 27, 30, 32) to the subscriber by the random processes 28, 31 and 33. This is continued until the time given to the call length in block 26 has elapsed and the call is released.

10   The resolution of the digital map is typically 50 x 50 m, and so it can be expected that the hand-portables remain in the same area pixel throughout the call. It can then be further expected that the load effects of the handportables appear mainly as

15   dynamic background load dependent on time and location. If required, the local intensity of this background traffic can be determined by means of the local density of the handportables, the call statistics and special area specific weighting co-

20   efficients. Such area specific weighting coefficients may be dependent on e.g. the population density and the area type (industrial/business/residential). Moreover, special areas such as fair areas and air-ports should be taken into account separately.

25   Various additional features can be added to the traffic model based on individual subscribers and random processes, if desired. For example, a traffic lights control simulation can be added to the above-mentioned crossroads behaviour, and so it is also

30   possible to model traffic congestion at the cross-roads. On the other hand, the addition of these features requires new random processes, which may slow down and complicate the simulations, whereas the benefits to be obtained may remain rather marginal.

35   In fact, the basic structure described above can be

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considered to enable a sufficiently accurate modelling of the subscriber mobility effects in the cellular radio network.

When simulating an existing operating network, the statistics of the blocks 21, 24 and 29 can be updated by the statistics of the operating network, as illustrated by block 37, so as to continuously tune up the mobility model.

Figure 3 shows a more detailed operational block diagram of the system block 3 of Figure 1 using a GSM/PCN network as an example. To facilitate the understanding the operation and parameters of the GSM network will be described first. The GSM network comprises more parameters than conventional analog networks, such as NMT. The basic parameters of each base station BTS are stored in a base station controller BSC. Among the most important parameters from the point of view of network planning are the power levels of the subscriber equipment MS and the base station BTS, i.e. the RF power control strategy. It optimizes the RF power output from the MS and the BTS while ensuring that the required power is sufficient to support adequate speech quality. The BTS controls the speech quality and sends the measuring results received from the MS and its own measuring results to the base station controller BSC in each SACCH multi-frame period (480 ms). If the quality of speech is not acceptable, the BSC searches for potential base stations (cells) for the hand-over. The cell selection and hand-over decisions are based on the above-mentioned measuring results and various para-meters. Such parameters include the received level and the reception quality. The BSC can maintain a table of up to 32 neighbouring cells for each BTS and store the levels as they are received. The BSC per-

forms the intra-BSC hand-overs autonomously. If there
is an inter-BSC hand-over to be performed, the BSC
sends a list of preferred cells to the mobile switch-
ing centre MSC, and the MSC performs the hand-over
5   according to the list. Generally the power control,
for both the BTS and the MS, runs independently and
in parallel with the hand-over process, but in some
cases the power control has connections with the
hand-over process. For example, a hand-over would be
10   a better choice than a power increase if some of the
neighbouring cells allows communication with a lower
transmission power level. With a proper choice of
power control (PC) and hand-over (HO) thresholds, the
BSC will maintain call quality by means of the power
15   control, and will propose a hand-over only when the
subscriber equipment MS actually reaches the border
of the serving cell. If both the HO and PC threshold
conditions are fulfilled, the hand-over has a greater
priority than the power control. In cases where the
20   hand-over cannot be made, the power increase may be
used as a first aid.

        In the measuring block 302 of Figure 3, the GSM
specific sampling functions are performed in order to
specify a local field strength and interference
25   environment. The measuring block has an interface 303
to the traffic block 4 and the NPS/X block 1 of
Figure 1. The measuring block 302 receives informa-
tion about the current location of the generated
active subscribers on the digital map from the block
30   4. The field strength values of the six strongest
base stations in the area pixel of the digital map in
which the active subscriber is located are obtained
directly from the field strength matrix of this par-
ticular area pixel, which matrix is found in the
35   block 1 as well as the frequency scheme of the net-

work to be planned and the location data of the base
stations.

The above-mentioned frequency scheme of the
network to be simulated forms a basis for the inter-
5   ference measurements performed by the block 302. The
frequency scheme is employed to identify possible
interfering base stations and other similar location
specific field strength values obtained from the
field strength matrix of the area pixel. The local
10   signal quality can be estimated by means of a
carrier/interference (C/I) analysis performed in each
area pixel. A corresponding bit error ratio value BER
and a signal quality classification can also be de-
termined on the basis of the C/I analysis. This can
15   be done by comparing the carrier of a specific chan-
nel with the carrier of an adjacent channel or with
the signals of other base stations utilizing the same
channel in the same network. The interference deter-
mination is performed by means of base station
20   specific field strengths calculated in the area
pixels of the digital map by checking the ratio
between each base station pair in each area pixel.
Interfering base stations are determined on the basis
of the frequency scheme, taking into account, e.g.,
25   all base stations utilizing the same frequencies as
the base station dominating in this particular area
pixel. To minimize unnecessary calculation, a thres-
hold value can be determined, on the basis of which
only the strongest interfering base stations are
30   taken into account.

In practice, a instantaneous interference
situation is, of course, dependent on the state of
the interfering base stations and channels and on the
influence of the power control. These features can be
35   allowed for during simulation by allocating a

specific channel for each generated call – in accordance with the frequency scheme and the channel tables – in conjunction with the locking to the base station. In this way only the interference effects

5 caused by the active channels are taken into account in the interference analysis. The effects of dynamic power control can be taken into account by performing the required summing and substraction procedures of the decibel values in connection with the adjust-

10 ments. Measurements between the subscriber equipment MS and the base station BTS further require distance data between the MS and the BTS, which can be determined on the basis of the distance between the location of the base station BTS and the current area

15 pixel of the subscriber equipment.

The block 301 includes the system functions associated with the channel control. The purpose of the block 301 is to control the channel allocation in conjunction with the lockings to the cells and hand-

20 overs, and to control the instantaneous sampling per-formed by the measuring block 302 on the basis of the channel state data. For this purpose the control block 301 maintains base station specific channel tables, which store channel allocation and state

25 data, e.g. if the channel is free or busy. In addition, the block 301 may contain extra system algorithms, such as discontinuous transmission or frequency hopping, as it controls the interference measurement, and the concrete effects of these

30 functions can be seen primarily in the channel specific interference analyses.

The block 304 comprises the system functions to be simulated, including especially the algorithms associated with the cell selection and the active

35 connection control, which can be modified by the

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operator via the user interface 5. In this specific case, the block 304 contains such system specific algorithms as the call set-up algorithm 305, the power control algorithm (PC) 306, the hand-over algorithm (HO) and the radio link failure algorithm (RLF) 308. The different control parameters associated with the algorithms are stored in a data base 309, in which the operator can modify them via the user interface 5. The block 304 further comprises a pre-processing 310 for samples collected by the measuring block 302. The pre-processing provides identification codes representing the state of each connection. On call set-up, the subscriber generated by the traffic block 4 on the digital map is locked, under the control of the call set-up algorithm 305, to a cell (base station) having the greatest field strength value in the area pixel in which the subscriber is located. The power control and channel change identification codes produced by the pre-processing 310 from the measuring results of the measuring block 302 are compared continuously with corresponding base station specific control parameters stored in the data base 309 in accordance with the power control algorithm 306 and the channel change algorithm 307. According to the RLF algorithm 304, the call is consider to be interrupted, if the quality of the connection remains below a predetermined threshold value for a sufficient period of time. The block 304 continuously exchanges channel state and allocation data with the control blocks 301.

As the primary function of simulation is to collect information about the operation of the network for subsequent analysis, the system functions performed during the simulation and their background

information, such as the measuring results of the
block 302 and the identification codes formed on the
basis thereof, are stored in the simulation result
data base 6 of Figure 1 as comprehensively as

5   possible. Especially the use of individual sub-
scribers in the simulation offers a possibility of
extremely diversified collection of data and further
applications. The storing of the different simulation
events can be e.g. street specific, location

10 specific, network element specific or cause specific.
Simulation events to be stored include at least call
set-ups, call releases, link failures, power controls
and change changes.

Even though it is also possible in the system

15 according to the invention to realize follow-up
during the simulation, the actual utility
applications of the simulation are accomplished by
post-processing the event statistics stored in the
data base 6. The aim is to screen out relevant

20 information, which can be performed by post-
processing programmes illustrated by the block 8 in
Figure 1. They can be classified according to their
degree of advancement as follows: graphics applica-
tions, analysing applications, and optimizing ap-

25 plications.

Graphics applications aim at processing the
event statistics created during the simulations into
visual graphic representations. Figure 4 shows a
hierarchical diagram of post-processed graphic rep-

30 resentations which the operator can, for instance,
select and output to a graphic user interface. The
uppermost horizontal row in Figure 4 shows statistics
on the entire network by means of histograms, wherein
each column in each histogram represents one mobile

35 switching centre MSC, for instance. The height of the

column in each column diagram can, in turn, represent traffic load, number of blocked calls, number of queueing calls, total number of calls, number of channel handovers, call quality, number of power con-
5   trols, number of link failures, etc. in the respective mobile switching centre MSC. The second horizontal row in Figure 4 shows the corresponding histograms for the base station controllers BSC con- trolled by the specific MSC, the third horizontal row
10   for the base stations controlled by the specific BSC, and the fourth horizontal row shows histograms repre- senting specific base stations. The simulations statistics can also be presented as graphic map pre- sentations, as illustrated by the bottommost row in
15   Figure 4. The block 400 illustrates e.g. events per area unit, the block 402 the distribution of the eve- nts on a certain route, and the block 402 illustrates events as a function of the radio environment on a certain route.
20   Similar graphic representations are also shown in Figure 5. Figure 5a illustrates the number of calls in the different mobile switching centres, and Figure 5b illustrates the call density in different network areas as a map presentation. Figure 5c shows
25   the number of calls of different qualities in each mobile switching centre by means of histograms, and Figure 5d illustrates the distribution of calls of different qualities as a map presentation. Figure 5e illustrates the number of channel changes for each
30   MSC, and Figure 5f illustrates the distribution of channel handovers as a map representation.
        This kind of event specific presentations enable a systematic evaluation of the relative performance of the different portions of the cellular
35   network or the individual network elements on the

basis of different criteria. Figure 6 shows an out-
line of a practical embodiment, in terms of which the
operation of the different network elements can be
evaluated on the basis of the field strength dis-
5   tribution of the call traffic delivered by them.
Figure 6a shows a histogram illustrating the number
of calls having a signal strength less or more than x
dBm separately for each MSC. It appears from Figure
6a that the number of connections of inferior quality
10   is relatively high at the MSC3. By selections made by
the operator through the user interface 5, lower
hierarchical levels in the network can be reached
(Figure 4), and so it can be seen that the poor con-
nections are concentrated in the base station con-
15   troller BSC3 among the base station controllers BSC
of the mobile switching centre MSC3 illustrated in
Figure 6b. On examining the base stations under the
control of the BSC3 by means of the graphic represen-
tation of Figure 6c, it is further to be seen that
20   the poor connections are concentrated at the base
station BTS3 and therein especially on the radio
channel 3, as appears from the histogram of Figure
6d. The signal strength of the base station BTS3 on
different routes can then be studied by means of the
25   map presentation of Figure 6e. Figure 6f shows
variation in the signal strength at different
sections of the routes shown in Figure 6e. By means
of this information, one can attempt to change the
structure, powers or parameters of the network
30   through the user interface 5 so that an adequate
signal strength can be achieved in the discovered
critical areas. The effect of the new set values is
then tested by a new simulation, whereafter the set
values are perhaps again changed on the basis of the
35   results obtained, etc. By proceeding iteratively in

this way, the network parameters and set values can finally be optimized.

Analysing applications are independent application programmes the purpose of which is to analyse the statistical information provided by the simulations. The software may, for instance, compare the simulation results with predetermined limit values and output any detected deviations to the operator through the user interface. On the basis of the results of the analyses it is possible to e.g. "blacklist" the network elements evaluated as the most critical from the view point of the performance criteria applied in each particular case. The analysis programmes can also be classified into similar event specific application fields as the above-mentioned graphic representations, and so problems associated with the operation of typical cellular networks can be identified and localized by means of them. One simple embodiment is a programme which performs the analysis shown in Figures 6a to 6f, and then outputs a list of base stations estimated to be the most critical in view of the field strength distribution. The determination and performance of the actual correction procedures still remains to be done by the operator through the user interface 5.

Optimizing applications represent the most advanced level of further processing software. These application programmes analyse the operation of the network autonomously and then define proper control procedures for optimizing the operation of the network. Optimization is usually attempted to be performed by correcting the network configuration, and so the adjustment of e.g. the base station parameters and the channel change control parameters of the net-

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work is of primary importance. The programmes operate iteratively, that is, the values of the control parameters affecting the event under adjustment are adjusted after each analysis. Thereafter a new simulation run is performed and the analyses are repeated. This is continued until the performance criteria set by the operator or the general termination criteria defined for the programme (number of iterations or performance time of the programme) are met. The optimizing applications can also be classified similarly as the graphic applications. One practical embodiment is a programme for optimizing cell areas and channel handovers, which searches for short-term channel change situations, for instance, and studies whether they are necessary for the call quality or maintenance. On the basis of the analyses the programme attempts to adjust the borders of the service areas of the concerned base stations by means of the power level and channel handover control parameters.

When simulating an operating, actual cellular network, information can be continuously provided for the system according to the invention by utilizing the statistics of the operating network, and the performance of the network can be monitored by means of the simulations performed by the system, so that optimal network structure, configuration and control parameters in view of the operational performance of the network can be found. These optimal values can be set or applied to the operating cellular network either manually or automatically. As shown in Figure 7, the system 70 according to the invention may have an interface 73 to an operation and maintenance centre OMC 72 of a GSM cellular network 71, e.g. an OMC commercially available from Nokia Cellular Inc,

the OMC providing information to the system 70 on the operation of the network 72 and enabling the system 70 to alter the network configuration, e.g. control parameters. So the operation of the cellular network

5   71 can be optimized continuously in accordance with current conditions. When the system 70 of the invention employs the above-mentioned autonomous analysing applications and applies optimized parameter values automatically to the OMC 72, a cellular network cap-

10   able of fully automatic adaptation is achieved.

The figures and the description related to them are only intended to illustrate the invention, which may vary in its details within the scope of the attached claims.

25

Claims:

1. A method of planning a cellular radio net-
work, comprising creating of a model representing the
cellular network and its radio environment on a
digital map, c h a r a c t e r i z e d in that the
method further comprises

adding of system properties affecting the traf-
fic control process of the cellular radio network in
connection with said model representing the cellular
radio network and its radio environment for route
specific operational simulation of the cellular radio
network,

optimization of the parameters of the cellular
radio network and full operational optimization of
the cellular network on the basis of statistical si-
mulation results describing the operation of the net-
work.

2. A method according to claim 1, c h a r a c -
t e r i z e d in that a traffic density model is
also added in connection with the model representing
the cellular radio network and its radio environment,
the traffic density model comprising a subscriber
mobility model, and that immobile and/or mobile
individual subscribers generated on the digital map
are used in the simulation.

3. A method according to claim 1 or 2, c h a r-
a c t e r i z e d in that the simulation events are
stored separately for each street, location, network
element and/or cause.

4. A system for planning a cellular radio net-
work, comprising

an interactive means (1) for creating a model
representing the cellular radio network and its radio
environment on a digital map comprising terrain and

topology information, the model comprising at least
base station locations and antenna locations, antenna
powers and antenna directions thereof so defined that
radio coverage areas calculated on the basis of a
5   predetermined radio signal propagation model and the
information provided by the digital map cover entire-
ly a desired geographical area,

characterized in that the system
further comprises

10   a means (4) for generating active subscribers
to be positioned on the digital map and radio links
established by said active subscribers for simulating
said model;

a means (302) for determining at least field
15   strength and interference conditions at each location
of each generated active subscriber during the radio
link in said model of the radio environment created
on the digital map;

a means (3) for simulating system functions
20   associated with the base station selection, base
station handover, channel allocation and active
connection control of the subscribers generated by
the generating means (4) on the basis of said
determined field strength and interference conditions
25   and in accordance with the selected system control
algorithms and parameters of the cellular radio net-
work; and

a means (6) for storing the event data of the
functions performed by the simulating means,

30   means (5) for changing the system control para-
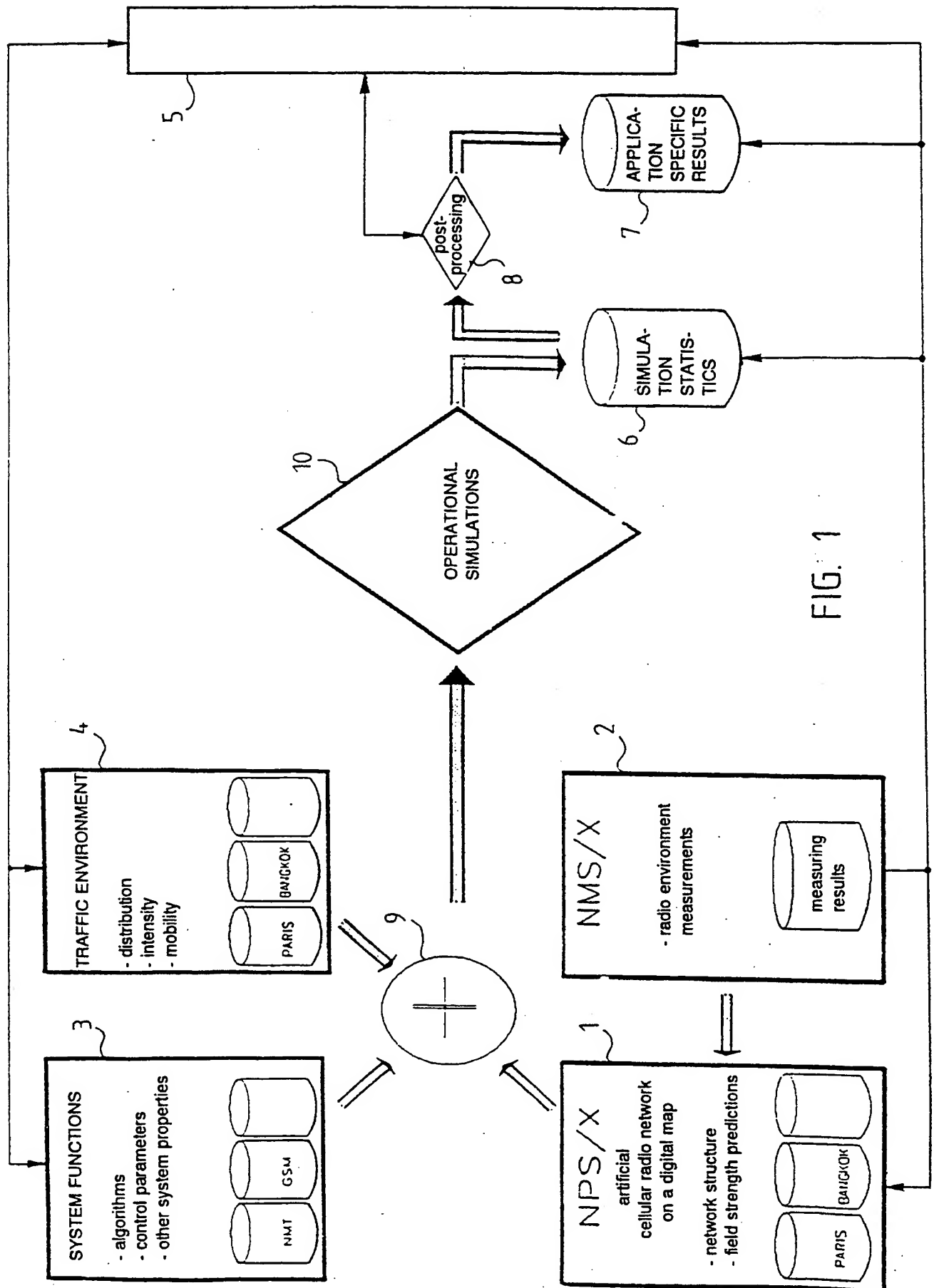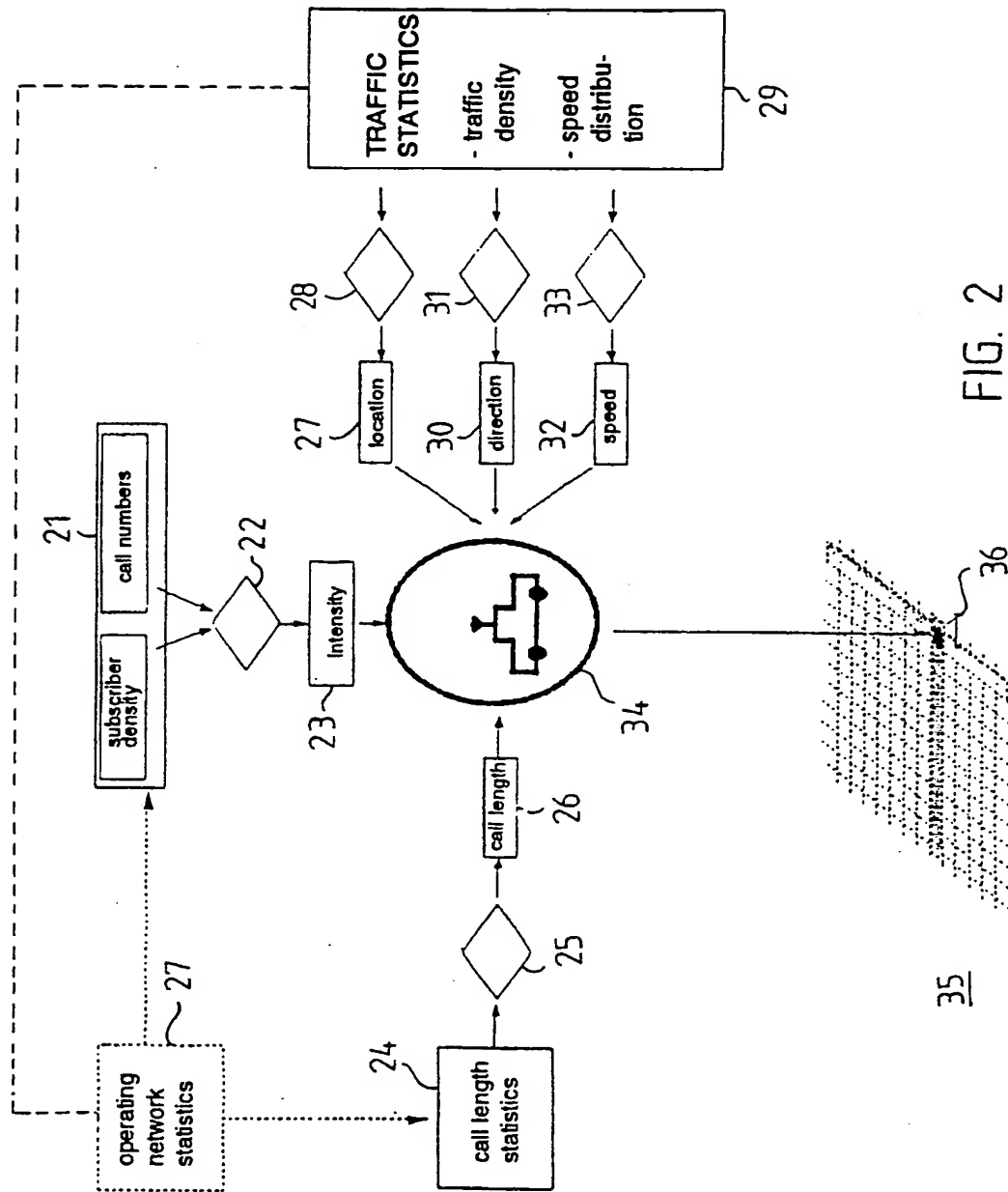meters on basis of the simulation results.

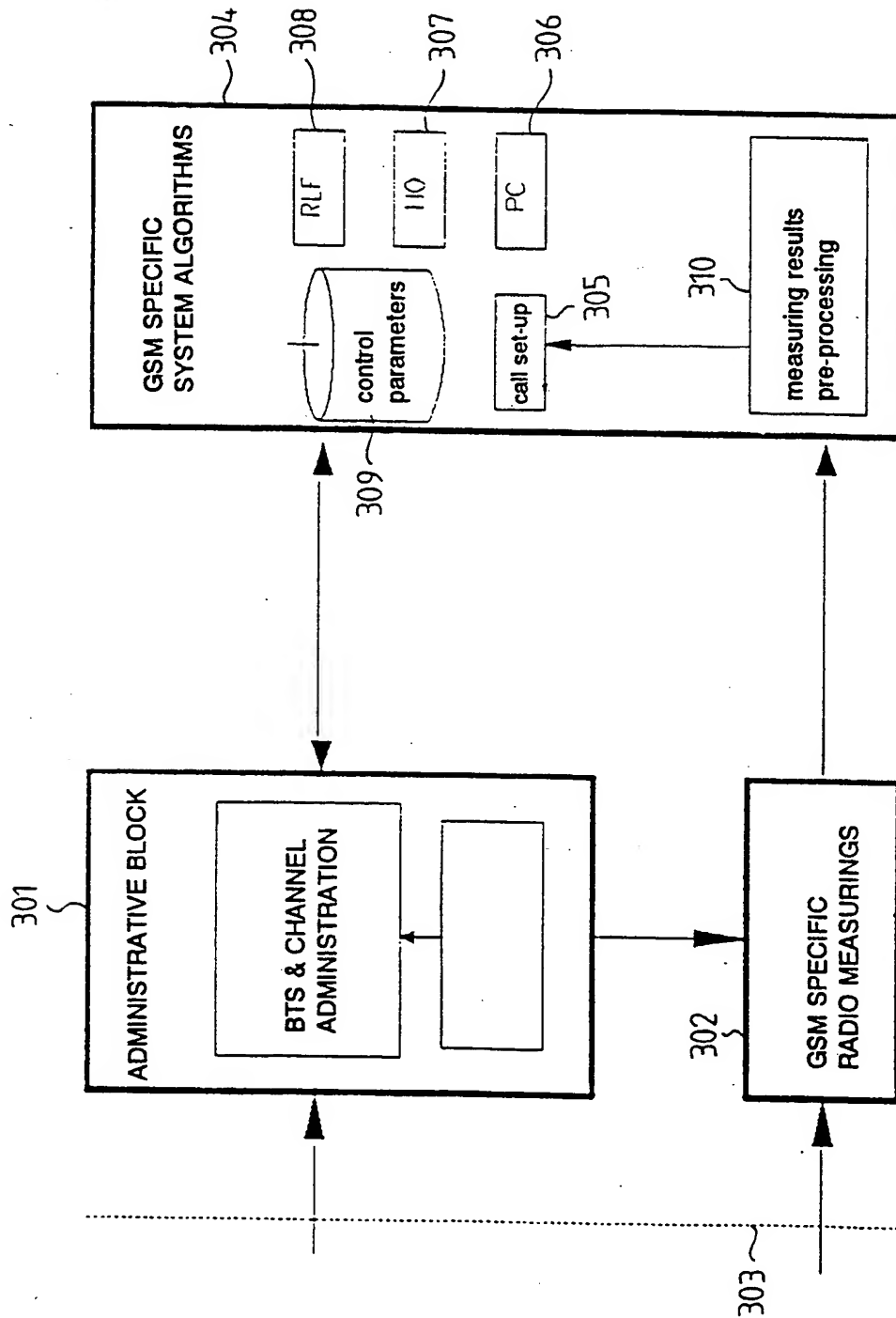5. A system according to claim 4, charac-
terized in that the generating means (4)
generates active subscribers by means of a random
35   process based on the actual call statistics and/or

subscriber penetration of the area to be simulated.

6. A system according to claim 4 or 5, c h a r-
a c t e r i z e d in that the generating means (4)
generates active subscribers moving in the street or
road network of the digital map by a random process
based on actual street specific traffic amount
statistics.

7. A system according to claim 4, 5 or 6,
c h a r a c t e r i z e d in that the generating
means (4) assigns each generated subscriber an
independent initial speed, direction and connection
time on the basis of predetermined statistical random
functions.

8. A system according to any of claims 4 to 7,
c h a r a c t e r i z e d in that the system com-
prises means (8) for statistically processing the
event data stored in the storing means (6) and for
graphically presenting the event statistics of a
graphic user interface (5).

9. A system according to any of claims 4 to 8,
c h a r a c t e r i z e d in that the system com-
prises means (5) enabling the operator to select and
process the graphic statistical presentations of the
graphic user interface.

10. A system according to any of claims 4 to 9,
c h a r a c t e r i z e d in that the system comp-
rises an interface (73) to a real operating cellular
network (71, 72) for receiving information about the
operation of the network.

11. A system according to any of claims 4 to
10, c h a r a c t e r i z e d in that the system
comprises an interface (73) to a real operating cel-
lular network (71, 72) for altering the network para-
meters manually or automatically.

12. Control system for a cellular radio net-

work, comprising means for obtaining statistical data
of operation of an operating cellular network and
means for altering control parameters of the cellular
network on the basis of said obtained statistical

5   data, c h a r a c t e r i z e d in that said means
for altering said control parameters further comprise

means (1) for storing a model of the cellular
radio network and its radio environment on a digital
map comprising terrain and topology information, the

10   model comprising at least base station locations and
antenna locations, antenna powers and antenna direc-
tions of the cellular network,

a means (4) for generating active subscribers
on the digital map and radio connections established

15   by said active subscribers according to said statis-
tical data obtained from the operating cellular net-
work,

a means (302) for determining at least field
strength and interference conditions at each location

20   of each generated active subscriber during the radio
link in said model of the radio environment created
on the digital map;

a means (3) for simulating system functions
associated with the base station selection, base

25   station handover, channel allocation and active
connection control of the subscribers generated by
the generating means (4) on the basis of said
determined field strength and interference conditions
and in accordance with the system control algorithms

30   and parameters of the cellular radio network; and

a means (6) for storing the event data of the
functions performed by the simulating means,

means (5) for changing the system control para-
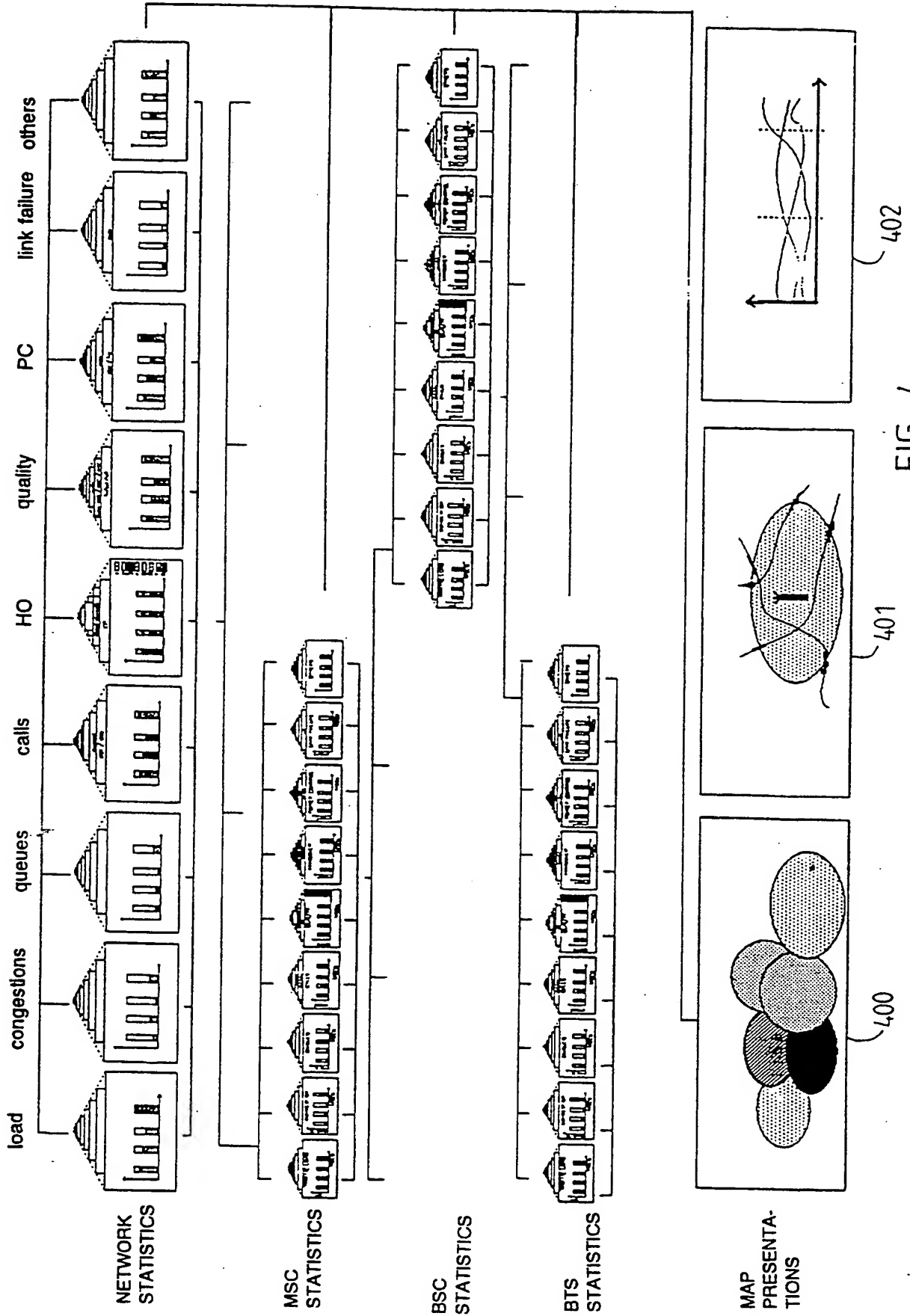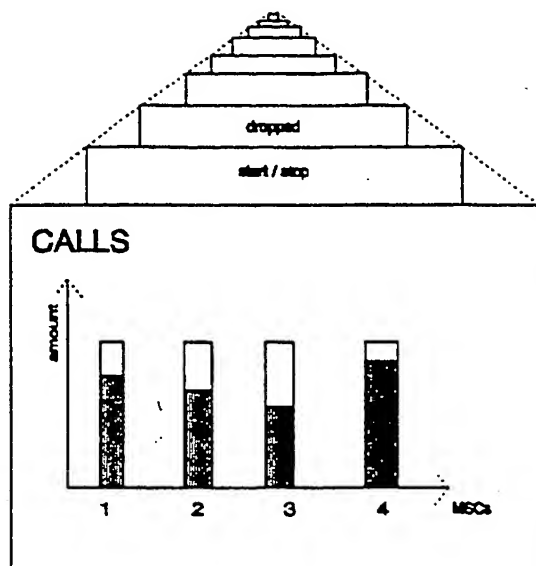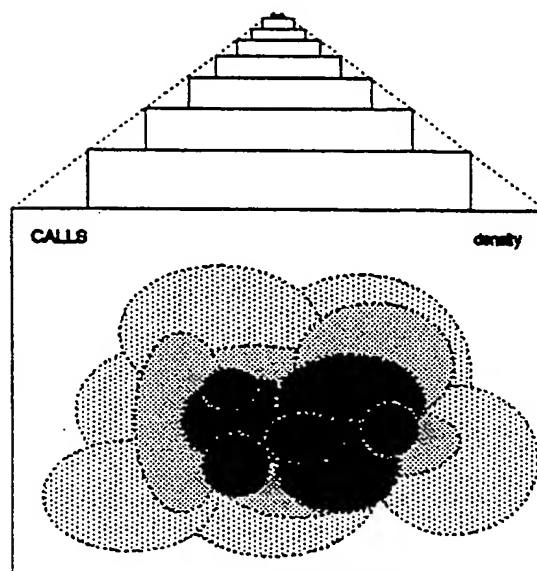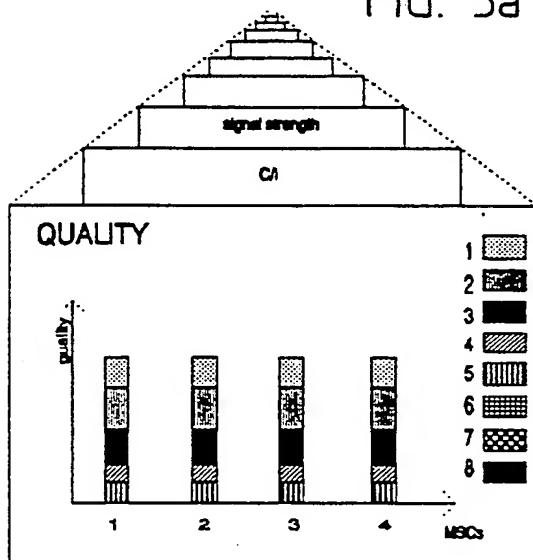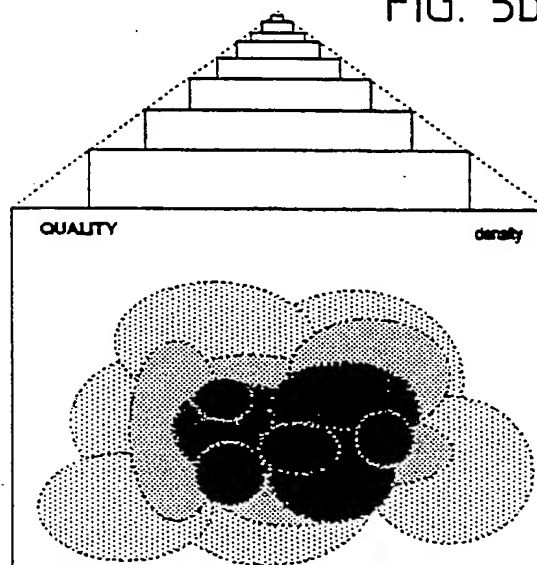meters on basis of the simulation results.

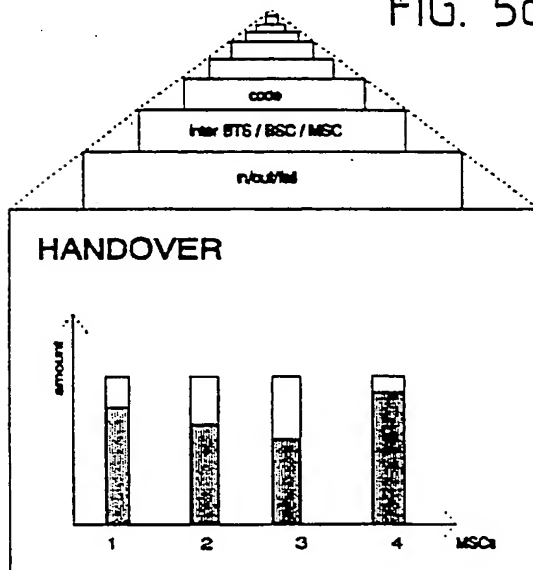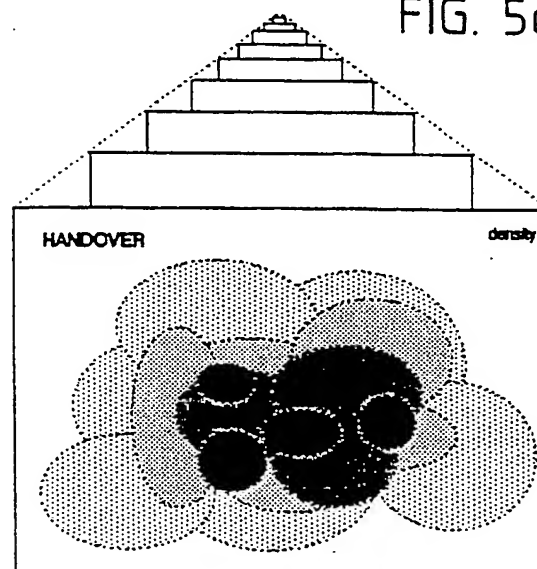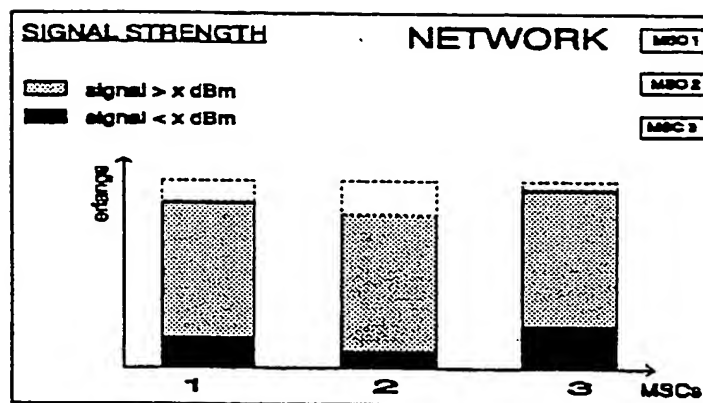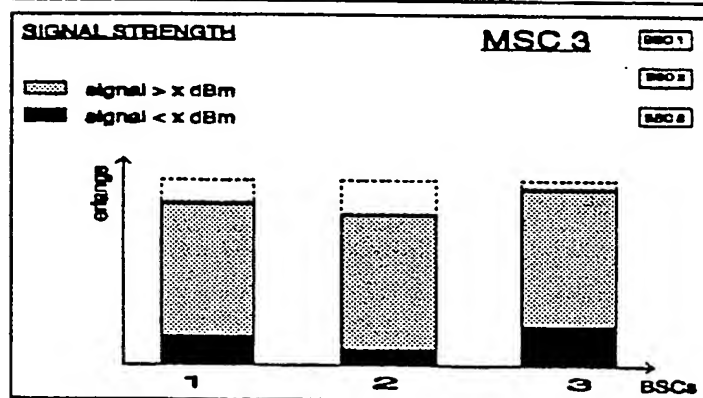FIG. 1

FIG. 2

FIG. 3

FIG. 4
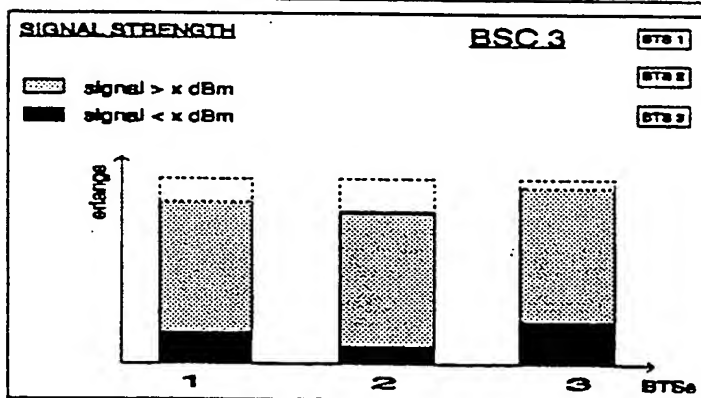
FIG. 5a

FIG. 5b

FIG. 5c

FIG. 5d

FIG. 5e

FIG. 5f

FIG. 6a

FIG. 6b

FIG. 6c

FIG. 6d

FIG. 6e

FIG. 6f

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

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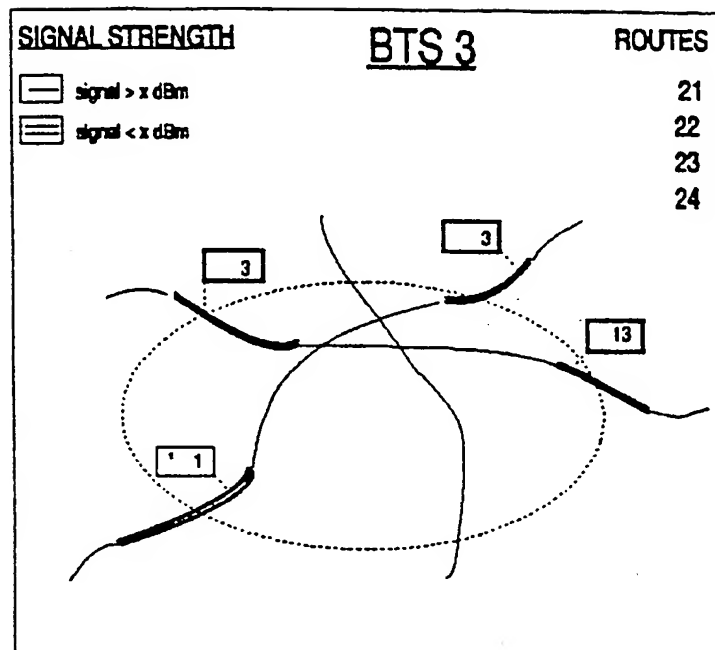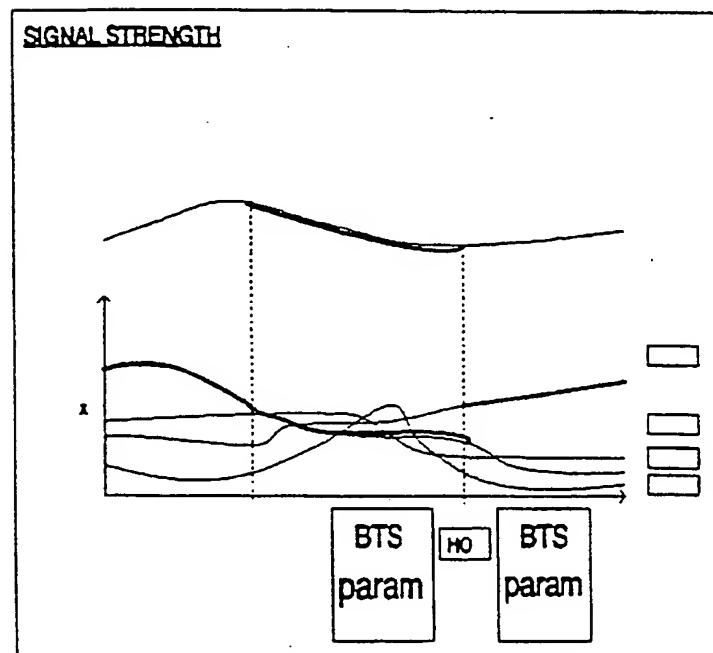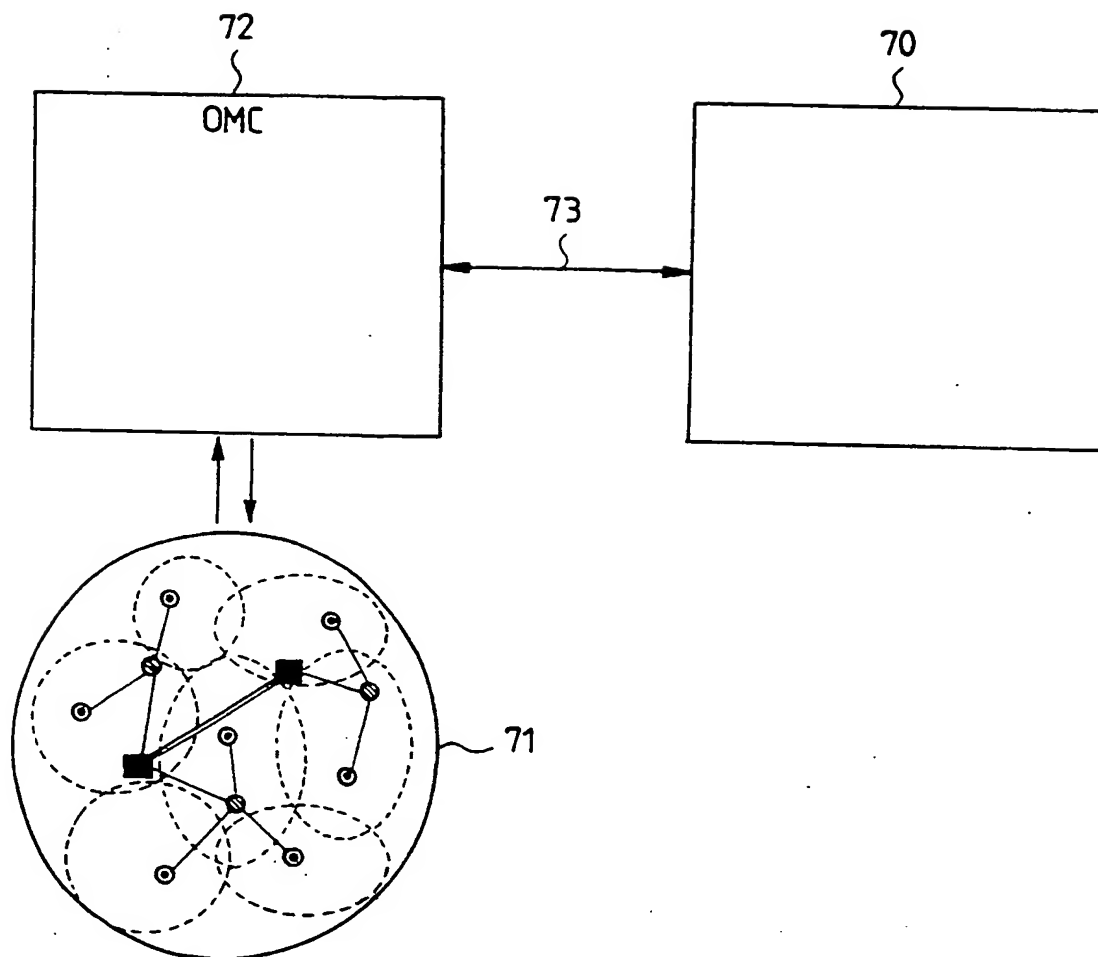## A. CLASSIFICATION OF SUBJECT MATTER

IPC5: H04Q 7/04, H04B 7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: H04Q, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	40TH IEEE VEHICULAR TECHNOLOGY CONFERENCE 6 May 1990, ORLANDO (US)pages 638-645 H.PANZER ET AL 'ADAPTIVE RESOURCE ALLOCATION IN METROPOLITAN AREA CELLULAR MOBILE RADIO SYSTEM' see page 638, right column, line 4 - line 14 and abstract, page 641, paragraph 3 - page 643, paragraph 3.5, page 644, paragraph 5 - paragraph 6	1-4
Y		5-11
	--	
X	WO, A, 9010342 (TELEVERKET), 7 Sept 1990 (07.09.90), see the whole document	1,2,4
Y		5-12
	--	

| X | Further documents are listed in the continuation of Box C. | | X | See patent family annex. |

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 1993	29 -04- 1993

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Margareta Nylander Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 93/00022

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP, A, 0431956 (MOTOROLA), 12 June 1991 (12.06.91), column 2, line 54 – column 3, line 30; column 5, line 42 – column 6, line 5; column 6, line 20 – column 7, line 25 --	12
A	NACHRICHTEN ELEKTRONIK UND TELEMATIK, Volume 45, No 1/2, January 1991, (HEIDELBERG DE), J. ALTHOFF , "Neue Plannungsansätze für zellulare Mobilfunknetze. Raum für Veränderungen", page 22 – page 25, see the whole document --	1,2,4,5,9-11
A	8TH EUROPEAN CONFERENCE ON ELECTROTECHNICS 13 June 1988, STOCKHOLM (US) pages 383-386; L. P. STRAUS ET AL: 'SIMULATION OF A WIRELESS PBX SYSTEM FOR OFFICES' see page 383, right column, line 32 – page 385, left column, line 10 -- --------	1-8

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO-A-	9010342	07/09/90	AU-B-	627858	03/09/92
			AU-A-	5273590	26/09/90
			EP-A-	0461192	18/12/91
			JP-T-	4504038	16/07/92
			SE-B,C-	465145	29/07/91
			SE-A-	8900744	04/09/90
			SE-B,C-	465247	12/08/91
			SE-A-	8900745	04/09/90
EP-A-	0431956	12/06/91	US-A-	5023900	11/06/91
			US-A-	5095500	10/03/92

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